CRREL

Draft Translation 549
October 1976

12
NW

CONSTRUCTING CONCRETE DAMS IN REGIONS WITH SUBZERO AVERAGE YEARLY TEMPERATURE

K.A. Mal'tsov et al

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Draft Translation 549

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): CONSTRUCTION OF CONCRETE DAMS IN AREAS WITH SUBZERO MEAN ANNUAL TEMPERATURE

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): K.A. Mal'tsov, et al

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

12. REPORT DATE: October 1976

13. NUMBER OF PAGES: 8

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DAMS

WINTER CONSTRUCTION

CONCRETE PLACING

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Building concrete hydraulic engineering structures in regions with severe climatic conditions characterized by a subzero average yearly temperature raises a number of problems which do not occur when dams are constructed in regions with a moderate or warm climate. These problems arise because of the complete freezing of a considerable amount of the embankment of a concrete dam during the operational period on the one hand, and the change in the thermomechanical properties of the concrete (coefficient of linear expansion, strength, modulus

over

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

of elasticity, etc.), on the other hand. This report addresses those problems.

A

(10) K. A. / Maltsov, Sh. N. / Plyam L. I. / Kudoyarov

(11) Oct 76

DRAFT TRANSLATION 549

(12) 12p.

(6)

ENGLISH TITLE: CONSTRUCTION OF CONCRETE DAMS IN AREAS WITH SUBZERO MEAN ANNUAL TEMPERATURE

FOREIGN TITLE: (STROITEL'STVO BETONNYKH PLOTIN V RAIONAKH S OTRITSATEL'NOI SREDNEGODOVOI TEMPERATUROI)

(14) CRREL-TL-549

AUTHOR: K.A. Mal'tsov, et al

(21) Trans. of

SOURCE: [redacted] Vsesoiuznyi nauchnoissledovatel'skii institut gidrotekhniki, Izvestiia, [redacted] v101 p133-138, 1973.

(USSR)

CRREL BIBLIOGRAPHY ACCESSIONING NO.: 29-3453

Translated by Office of the Assistant Chief of Staff for Intelligence for U.S. Army Cold Regions Research and Engineering Laboratory, 1976, 8p.

NOTICE

The contents of this publication have been translated as presented in the original text. No attempt has been made to verify the accuracy of any statement contained herein. This translation is published with a minimum of copy editing and graphics preparation in order to expedite the dissemination of information. Requests for additional copies of this document should be addressed to the Defense Documentation Center, Cameron Station, Alexandria, Virginia 22314.

037100

1/B

UDC 627.824.012.4

CONSTRUCTING CONCRETE DAMS IN REGIONS WITH SUBZERO AVERAGE YEARLY TEMPERATURE

IZVESTIYA VSESOYUZNOGO NAUCHNO-ISSLEDOVATEL'SKOGO INSTITUTA GIDROTEKHNIKI in Russian Vol 101, 1973 pp 133-138

[Article by K. A. Mal'tsov, doctor of technical sciences, Sh. N. Plyam, doctor of technical sciences, and L. I. Kudoyarov, candidate of technical sciences]

[Text] Building concrete hydraulic engineering structures in regions with severe climatic conditions characterized by a subzero average yearly temperature raises a number of problems which do not occur when dams are constructed in regions with a moderate or warm climate. These problems arise because of the complete freezing of a considerable amount of the embankment of a concrete dam during the operational period on the one hand, and the change in the thermomechanical properties of the concrete (coefficient of linear expansion, strength, modulus of elasticity, etc.), on the other hand.

Figures 1, 2 and 3 show the temperature field* in the vertical profile of various sections of the concrete dam at the Kolymskaya GES (variant of the plan). The climatic conditions of the construction region are very severe: the average yearly air temperature is -12.0°C, the average temperature in January is -38°C; over 90 days a year have an average daily temperature of -30° and below. The construction region is in an area with a continuous occurrence of perennially frozen rock ("permafrost"). The frozen ground is 100-200 m thick. As can be seen from Figure 1, in the operational period, three-fourths of the width of the profile of the section of the spillway dam will be frozen. In the summer months the concrete on the downstream face of the dam thaws to a depth of 2-3 m. In the foundation the subzero temperature area extends to a depth of 6-9 m; the temperature of the rest of the foundation is above zero.

* All the data given in the article on the temperature conditions of dams were obtained as the result of calculations on a digital computer using the method developed at the All-Union Scientific Research Institute imeni V. Ye. Vedeneyev.

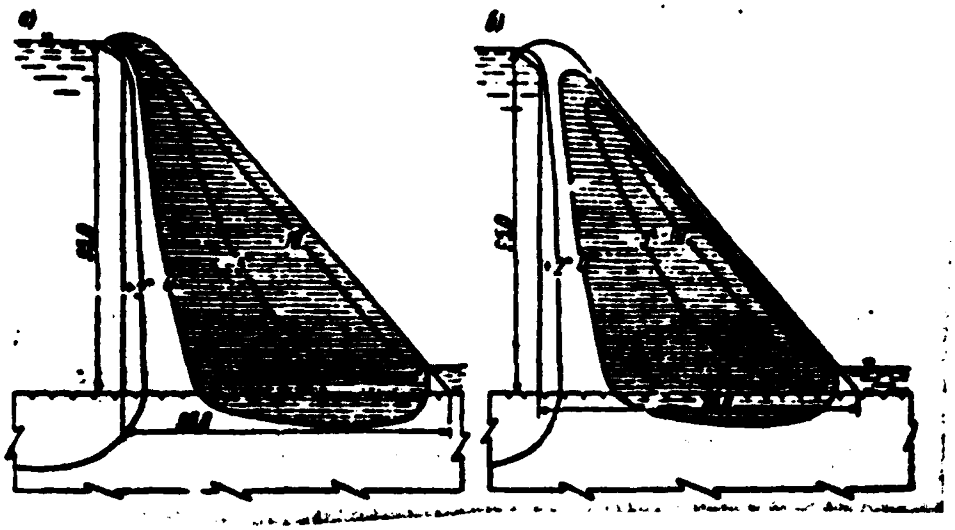

Figure 1. Temperature Field of Section of Spillway Dam in Operating Period (Kolyma River Region)

a) on 15 January; b) on 15 July

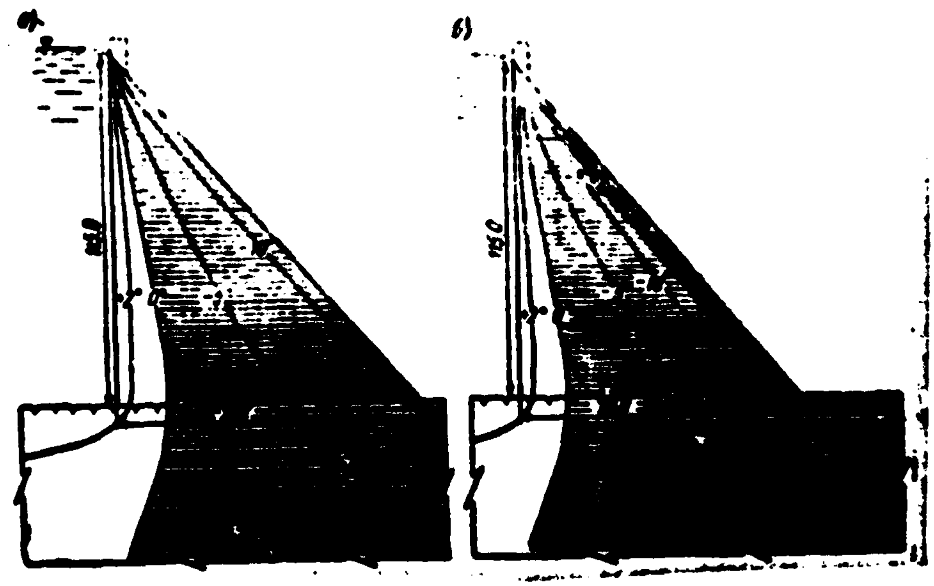

Figure 2. Temperature Field of Section of Enclosed Dam Located at Upper Levels Near Canyon Rims (Kolyma River Region)

a) on 1 January; b) on 1 July

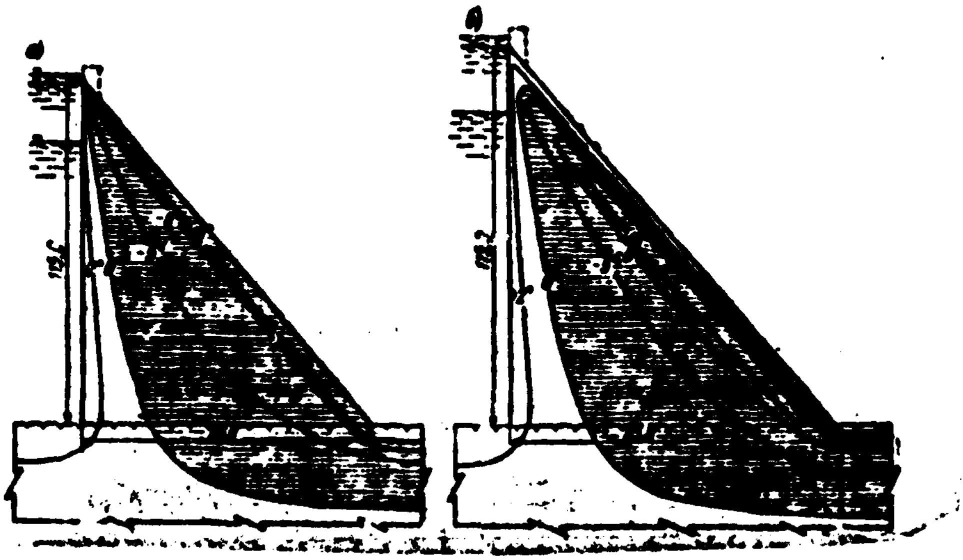

Figure 3. Temperature Field of Section of Enclosed Dam Located at Lower Levels Near Canyon Rims (Kolyma River Region)

a) on 15 January; b) on 15 July

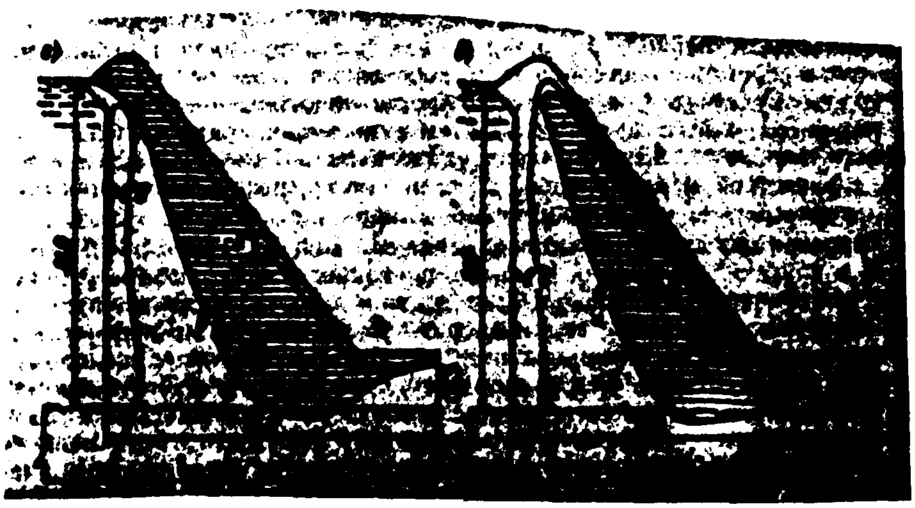

Figure 4. Temperature Field of Section of Spillway Dam in Operating Period (Ust'-Ilimskaya GES Region)

a) on 15 January; b) on 15 July

In the foundation of the sections of a spillway dam which are located in the channel part of the site, the thawed ground freezes to a depth of up to 6-9 m from the side of the toe of the structure.

The foundation of the other sections of a spillway dam during operation will gradually pass from a state of permafrost to a thawed state and the subzero temperature zone in the structure will adjoin the permafrost zone of the foundation for a long time. In this period a counter pressure curve will be in effect along the toe of the dam.

The sections of the enclosed river bank of the dam are under various conditions during the operating period: under the sections which are located at the upper levels near the rims of the canyon, the foundation is frozen through (figure 2); under the sections closer to the center of the dam, the foundation is only partially frozen through (Figure 3). High counter pressure may develop along the toe of this part of the sections.

The temperature conditions of a concrete dam constructed in a region with a moderately subzero average yearly temperature are illustrated from the example of the Ust'-Ilim hydraulic engineering system.

The region in which the Ust'-Ilim hydraulic engineering system is constructed is distinguished by a sharply continental climate. The average yearly temperature of the air is -3.9°C. For 120 days of the winter period there is an average daily temperature of the air below -15°C, and for 95 days, below -20°C. The difference between the maximal summer and minimal winter temperatures of the air reaches 94°C. Results of calculating the temperature field of the dam of the Ust'-Ilimskaya GES are shown in figures 4 and 5.

The zero isotherm passes along the center of the width of the spillway dam section from its crest to the foundation, drops into the rock to a depth of 2-2.5 m, diverging toward the tailwater, and then returns to the dam at a distance of approximately one-fourth of its width along the foundation from the downstream shell (Figure 4). Then the zero isotherm emerges at the downstream face of the dam at the tailwater level. In summer, because of the seasonal changes in air temperature, the concrete of the downstream face of the dam thaws to 3-4 m. The subzero temperature zone in the toe of the blank dam is 2-2.5 m closer to the headwater than the corresponding sections of the spillway dam (Figure 5). On the tailwater side the foundation proves to be frozen through to a considerable depth.

The calculating studies given show that, depending on the magnitude of the average yearly subzero temperature in the hydraulic engineering system region, two types of thermal states should be differentiated for the dam in the operational period: 1) a substantial part of the dam structure is permanently frozen (average yearly air temperature is -8°C and below); 2) about half of the structure of the dam from the tailwater side is permanently frozen (average yearly air temperature is -7÷-2°C). This

division is to a certain extent conditional. For example, some sections of the first type of them will be only partially frozen through.

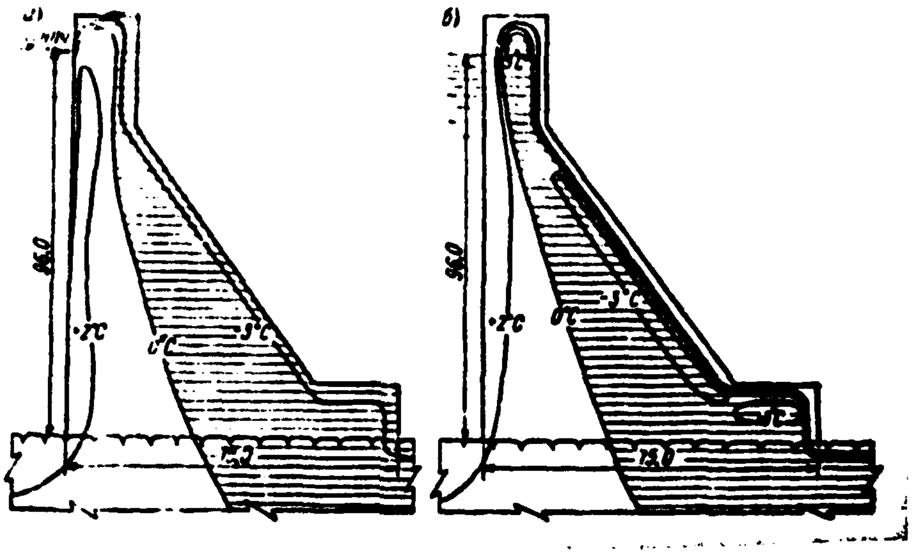

Figure 5. Temperature Field of Section of Enclosed Dam in Operating Period (Ust'-Ilimskaya GES Region)

a) on 15 January; b) on 15 July

The experimental studies of the All-Union Scientific Research Institute of Hydraulic Engineering imeni V. Ye. Vedeneyev [2-5], the Scientific Research Institute of Concrete and Reinforced Concrete [6, 7] and other organizations [8] showed that with subzero temperatures, concrete has higher strength indices than at above-zero temperatures. The deformation characteristics of the frozen concrete and concrete at above-zero temperatures are also different. For example, it was determined in work [3] that the strength of the samples of natural moisture content increased by 25-60 percent when frozen, and the value of the modulus of elasticity increased by 15-20 percent. In this case the greatest increase in strength was observed in the range of 0-ƺ-10°C. The coefficient of linear expansion of concrete when it is frozen increases [2, 3, 4, 6, 9]. Taking into account the temperature conditions of the structure, the high strength indices of the concrete and its favorable deformation characteristics at subzero temperatures can not only increase the reliability and crack-resistance of dams, but can also give a substantial economic saving in their construction and operation [9, 10].

At present, planning concrete dams for Siberia and the Far East mainly amounts to adapting certain types of concrete gravity or roundhead buttress

dams for work in regions with a severe climate: special measures are taken to maintain above-zero temperatures in the dams and the drainage system is almost a complete copy of known design solutions, etc.

Under these conditions, developing new types of concrete gravity and roundhead buttress dams especially for regions with a subzero average yearly temperature becomes very important. The task posed is an important national economic problem. Major comprehensive calculating-theoretical, experimental, design, technological and technical-economic studies are required for its solution.

1. Calculating-theoretical studies should be concerned with the following problems:

a) Calculating and analyzing the temperature conditions of the dams; here, along with considerations of the special features of the process of erecting and designing the dams, particular attention should be paid to the phenomena of seepage in the foundation of the structure;

b) Calculating and analyzing the state of stress of the dams. Since the deformation characteristics of concrete at subzero temperatures are considerably different from the deformation characteristics of concrete at above-zero temperatures, and since with any structural measures there will be zones of both subzero and above-zero temperatures in the dam, an estimative analysis must be made of the state of stress of the dams, the concrete of which has different mechanical characteristics in different zones of the structure; in this case attention should be given to the temperature-moisture content changes, the intrinsic weight, hydrostatic pressure and other types of power forces;

c) Studying the physical-chemical nature of the processes taking place when the concrete freezes.

2. Experimental studies should be made in two directions:

a) Experimental studies of the strength and deformation characteristics of concrete at subzero temperatures. Particular attention should be paid to testing the concrete for the prolonged action of a load, selecting the compositions of the concrete for work under subzero temperatures and studying the behavior of reinforced concrete.

Tests should be made both under laboratory conditions using large-dimension models and under natural conditions, directly at the hydraulic engineering structures;

b) Model studies of the hydraulic engineering structures should be made along the line of formulating a model study theory, selecting model materials, designing instruments and equipment to measure the deformation and forces. developing new methods of measuring deformations and forces, new methods of

measurements using the most recent achievements of physics and acoustics, etc. Particular attention should be paid to problems of model study of zones of frozen concrete and opening of the intercolumnar joints.

3. When making design studies, a distinction should be made between regions with a low subzero average yearly temperature (-8°÷-14°C) and with a moderate subzero average yearly temperature (-2°÷-8°C). Each of these regions should have its own optimal structural types of dams worked out for it and its own structural measures to regulate the temperature conditions for them. This is equally true of the different sections of the same dam. Since the temperature condition for the dam, characteristic for the operational period, is achieved over a period of 20-40 years from the beginning of the construction, a construction process must be developed under which, by the time the pressure is raised, the temperature field of the structure would correspond to a quasistationary one. This will substantially reduce the time for establishing the operational temperatures in the structure.

When developing new types of dams, particular attention should be paid to their technical-economic substantiation with a high degree of structural reliability.

BIBLIOGRAPHY

1. Plyat, Sh.N. "Methods of Calculating the Thermal Regime of the Concrete Blocks of Hydrualic Engineering Structures," IZVESTIYA VNIIG, Vol 84, 1967, pp 298-342.

2. Staritskiy, P.G., and Kats, A.S. "Izmeneniye deformatsiy i prochnostnykh svoystv betona pri zamorazhivanii. Trudy koordinatsionnykh soveshchaniy po gidrotekhnike" [The Change in Deformations and Strength Properties of Concrete With Freezing. Works of the Coordination Meetings on Hydraulic Engineering], No 13, Energiya, 1964, pp 149-162.

3. Plyat, Sh. N., and Kats, A.S. "Experimental Study of the Strength and Deformation Characteristics of Concrete at Subzero Temperature," IZVESTIYA VNIIG, Vol 83, 1967 pp 180-193.

4. Eydel'man, S.Ya., and Durcheva, V.N. "The Coefficient of Linear Expansion of Block Concrete at Subzero Temperature," IZVESTIYA VNIIG, Vol 84, 1967, pp 158-169.

5. Eydel'man, S. Ya. "Naturnyye issledovaniya plotiny Bratskoy GES" [Studies at the Site of the Dam of the Bratskaya GES], Energiya, 1968, p 255.

6. Mironov, S.A. "Teoriya i metody zimnego betonirovaniya" [The Theory and Methods of Winter Concreting], Gosstroiyzdat, 1956, p 405.

7. Moskvin, V. Ye.; Kapkin, M.M.; and Mazur, V.M. "Temperature Deformation of Concrete at Subzero Temperatures," GIDROTEKHNICHESKOYE STROITEL'STVO, No 6, 1964, pp 17-21.

8. Gorchakov, G.I.; Kapkin, M.M.; and Skramtayev, B.G. "Povysheniye morozostoykosti betona v konstruktsiyakh promyshlennykh i gidrotekhnicheskikh sooruzheniy" [Increasing the Freezing Resistance of Concrete in the Designs for Industrial and Hydraulic Engineering Structures], Moscow, 1965, pp 190-194.

9. Mal'tsov, K.A., and Staritskiy, P.G. Authorship Certificate No 187592 (USSR). Publ. in B.I., No 20, 1966, p 219.

10. Mal'tsov, K.A.; Shtamburg, N.G.; and Belen'kiy, B.S. Authorship Certificate No 282997, Publ. in B.I., No 30, 1970, p 195.